Effect Of Intake Pressure And Temperature On Auto-Ignition Of Fuels With Different Cetane Number And Volatility

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2012-01-1317

Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE **12 APR 2012**	2. REPORT TYPE **Briefing Charts**	3. DATES COVERED **12-04-2012 to 12-04-2012**

4. TITLE AND SUBTITLE **EFFECT OF INTAKE PRESSURE AND TEMPERATURE ON AUTO-IGNITION OF FUELS WITH DIFFERENT CETANE NUMBER AND VOLATILITY**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Eric Sattler; C. Jayakumar; U. Joshi; Z. Zheng; W. Bryzik**	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army TARDEC ,6501 E.11 Mile Rd,Warren,MI,48397-5000**	8. PERFORMING ORGANIZATION REPORT NUMBER **#22764**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **U.S. Army TARDEC, 6501 E.11 Mile Rd, Warren, MI, 48397-5000**	10. SPONSOR/MONITOR'S ACRONYM(S) **TARDEC** 11. SPONSOR/MONITOR'S REPORT NUMBER(S) **#22764**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Briefing charts presented to SAE World Congress 2012

14. ABSTRACT
Briefing Charts

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**27**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Outline

- Motivation and goals
- Diesel cycle simulation
- Analysis of auto-ignition processes
- Experimental investigations:
  ULSD, S-8, JP-8 (44), JP-8 (31)
- Experimental results and discussions
- Conclusions
- Acknowledgements

Motivation and goals

- Motivation:
  - Depletion of petroleum reserves
  - Rising fuel costs & Security of supply
  - Alternate fuels possess a wide range of properties

- Goals:
  - To investigate the chemical and physical processes during auto-ignition of different fuels

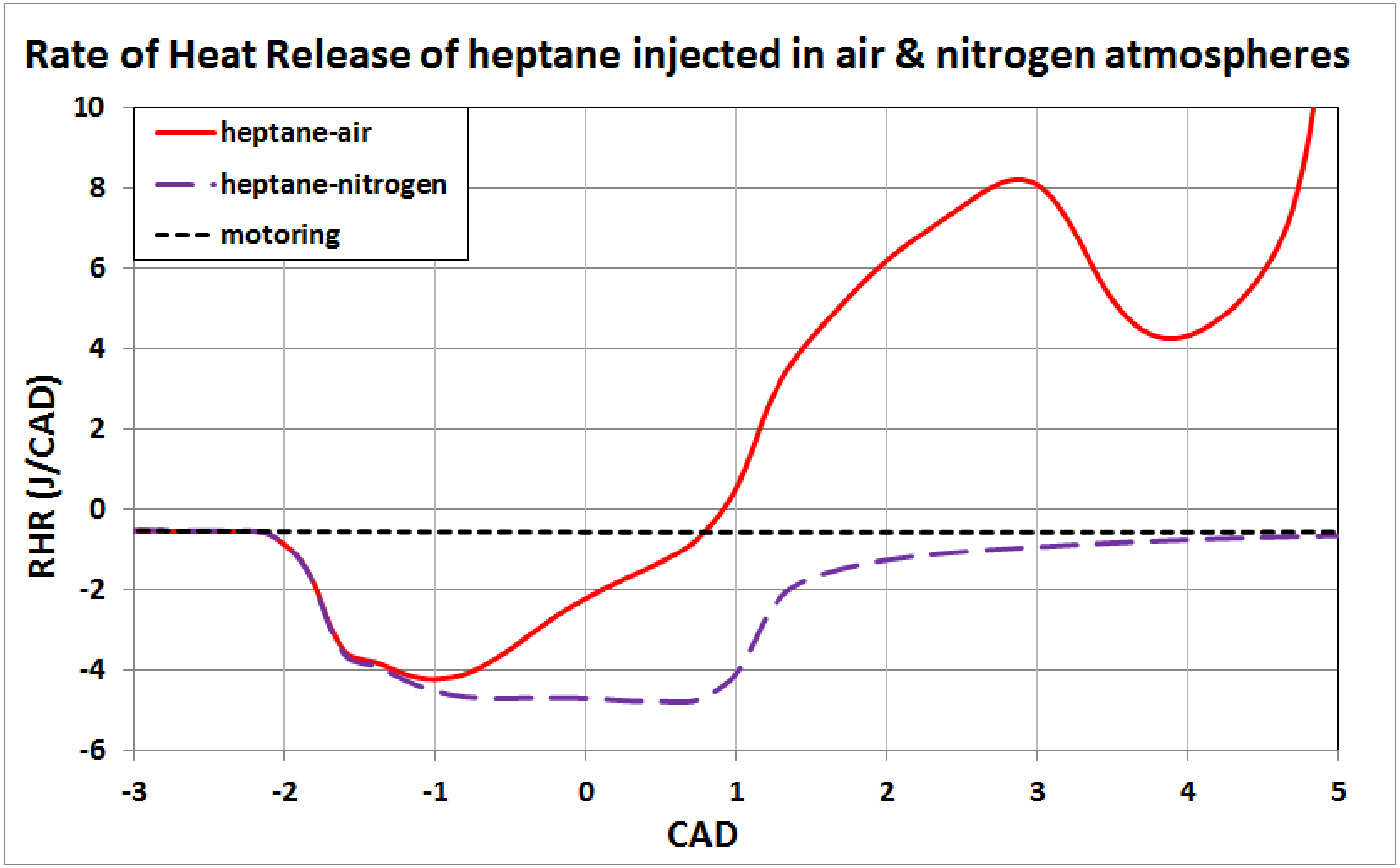
- Approach:
  - Computer simulations validated by experimental results at different intake pressures and temperatures using fuels with different cetane number and volatility

Simulation Results/Findings

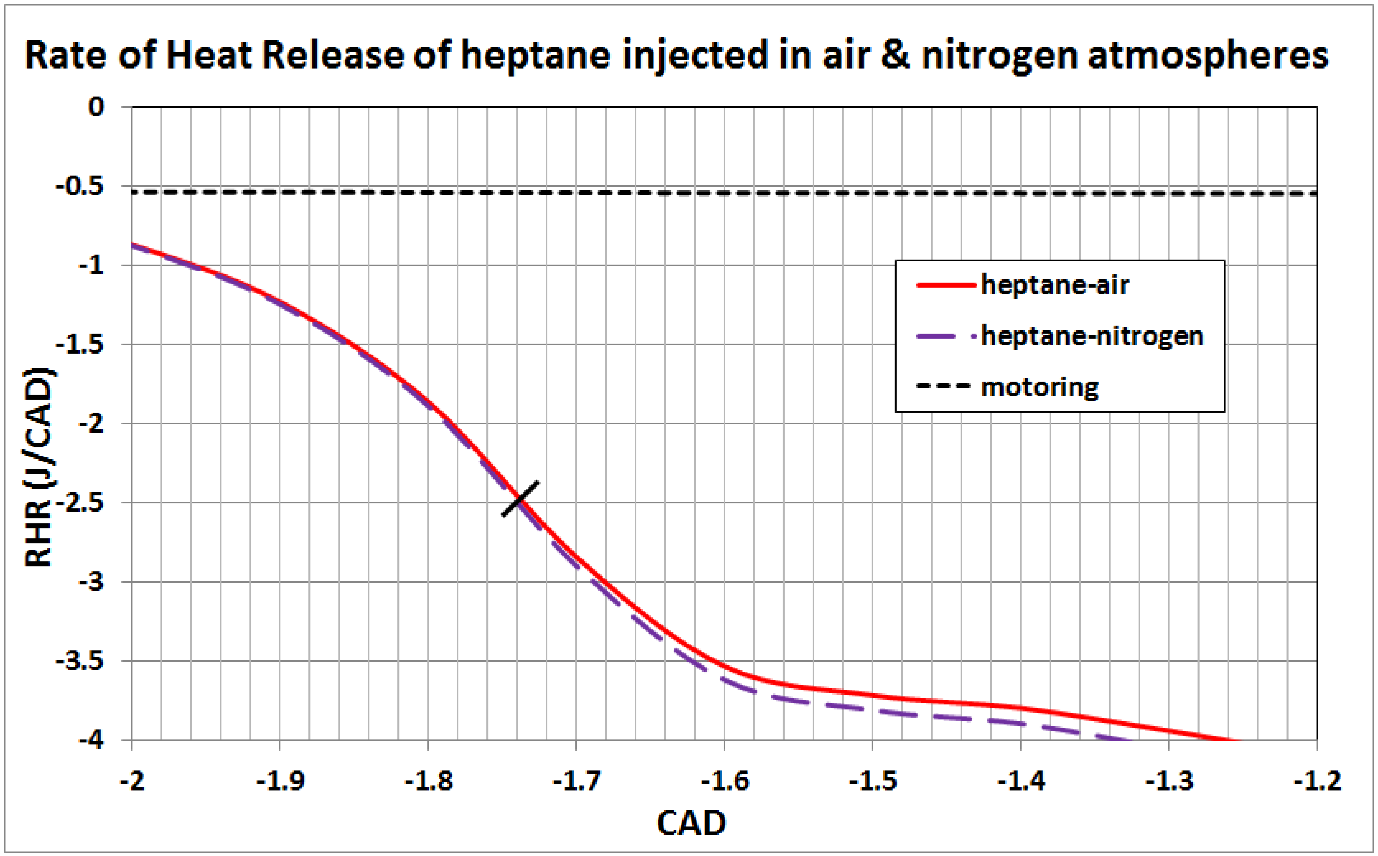
Diesel cycle simulation

- Model: 3D-CFD simulation software coupled with the chemistry of auto-ignition and combustion
- Mechanism: Reduced n-Heptane Mechanism with 33 species & 122 reactions
- Engine: PNGV single cylinder, direct injection diesel engine equipped with a common rail injection system
- Conditions:
  - 1500 rpm, Swirl: 3.77, P_{inj}: 800 bar, SOI: 2.2 CAD bTDC, Intake pressure 1.1bar-1.5bar, Intake temperatures: 80°C-190°C

Simulation Results

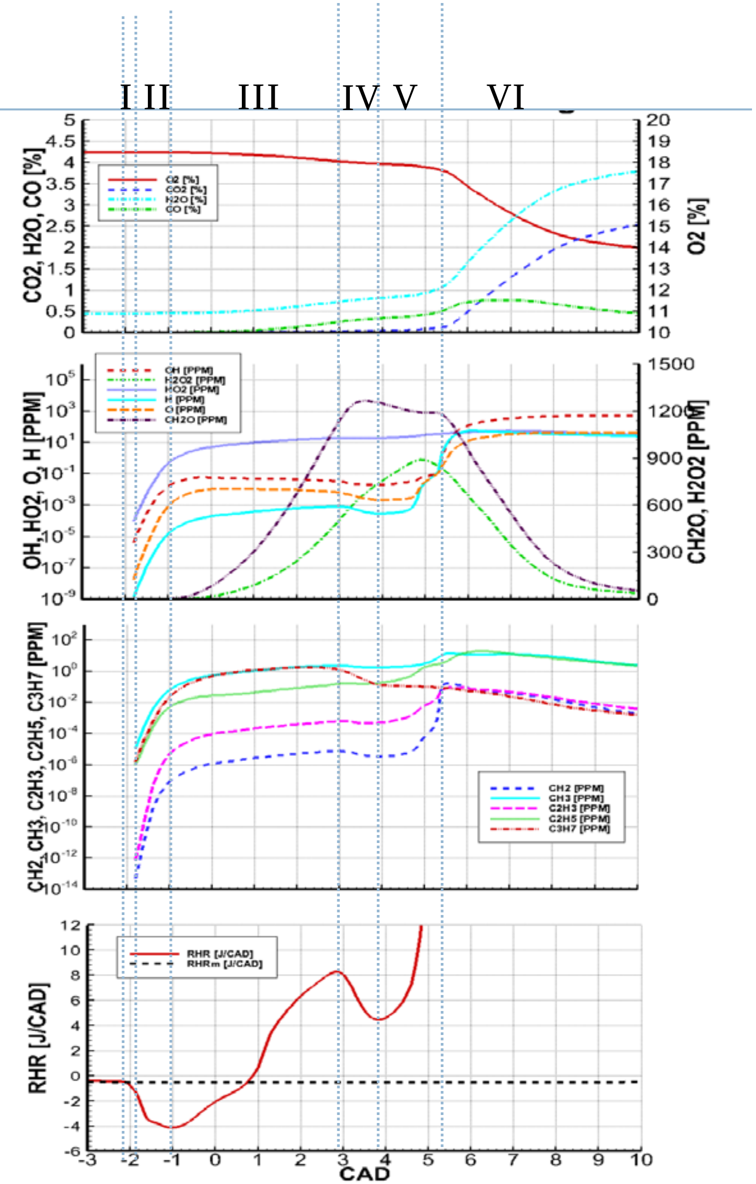


Point of Inflection – Beginning of Exothermic Reactions

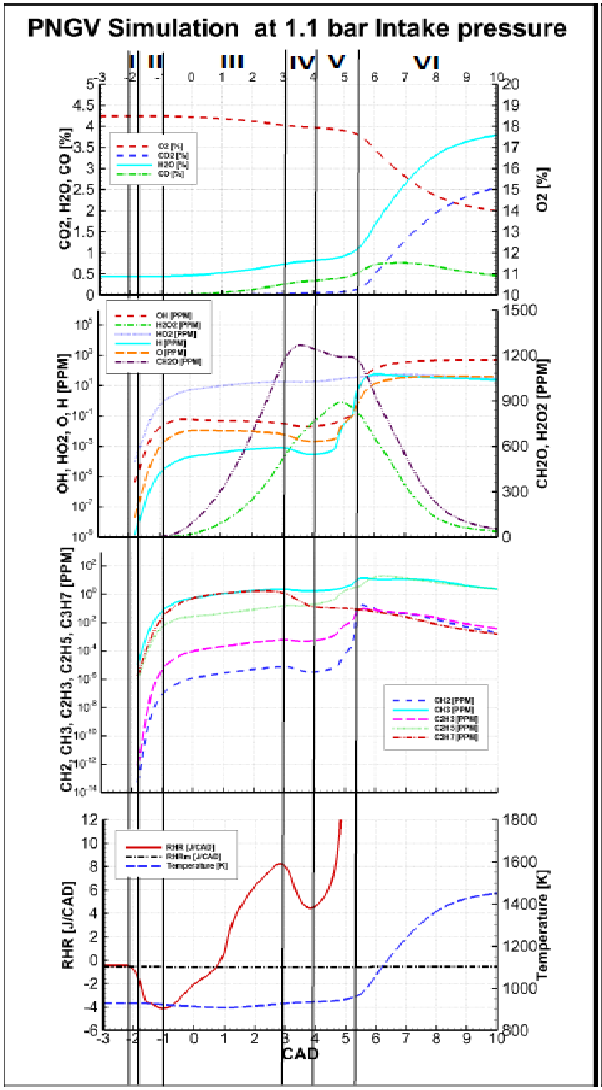


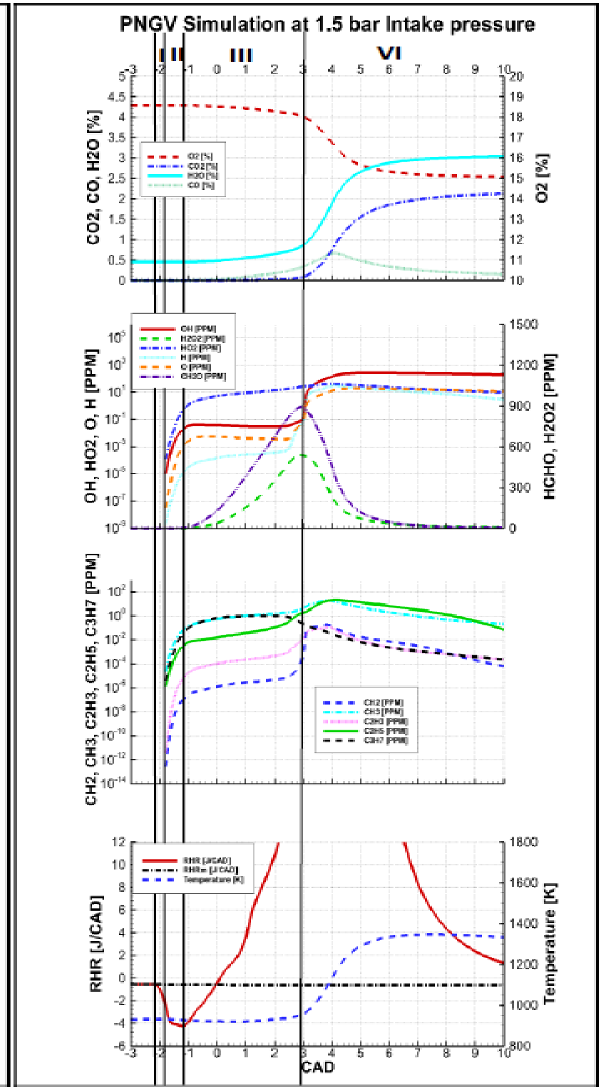
Analysis of Auto-ignition processes

- **Zone I:** Fuel evaporation
- **Zone II:** Endothermic reactions, fuel break-down, beginning of exothermic reactions
- **Zone III:** LT regime, formation of HCHO, H2O2, species formation slowing down (plateau)
- **Zone IV:** NTC regime, HCHO reaches peak, species conc dropping (valley)
- **Zone V:** Increase in other species, H2O2 reaches peak, HCHO reaches a second peak
- **Zone VI:** Main combustion, HCHO, O2 starts to drop, H2O2 drops faster, CO2 and H2O starts increasing a faster rate

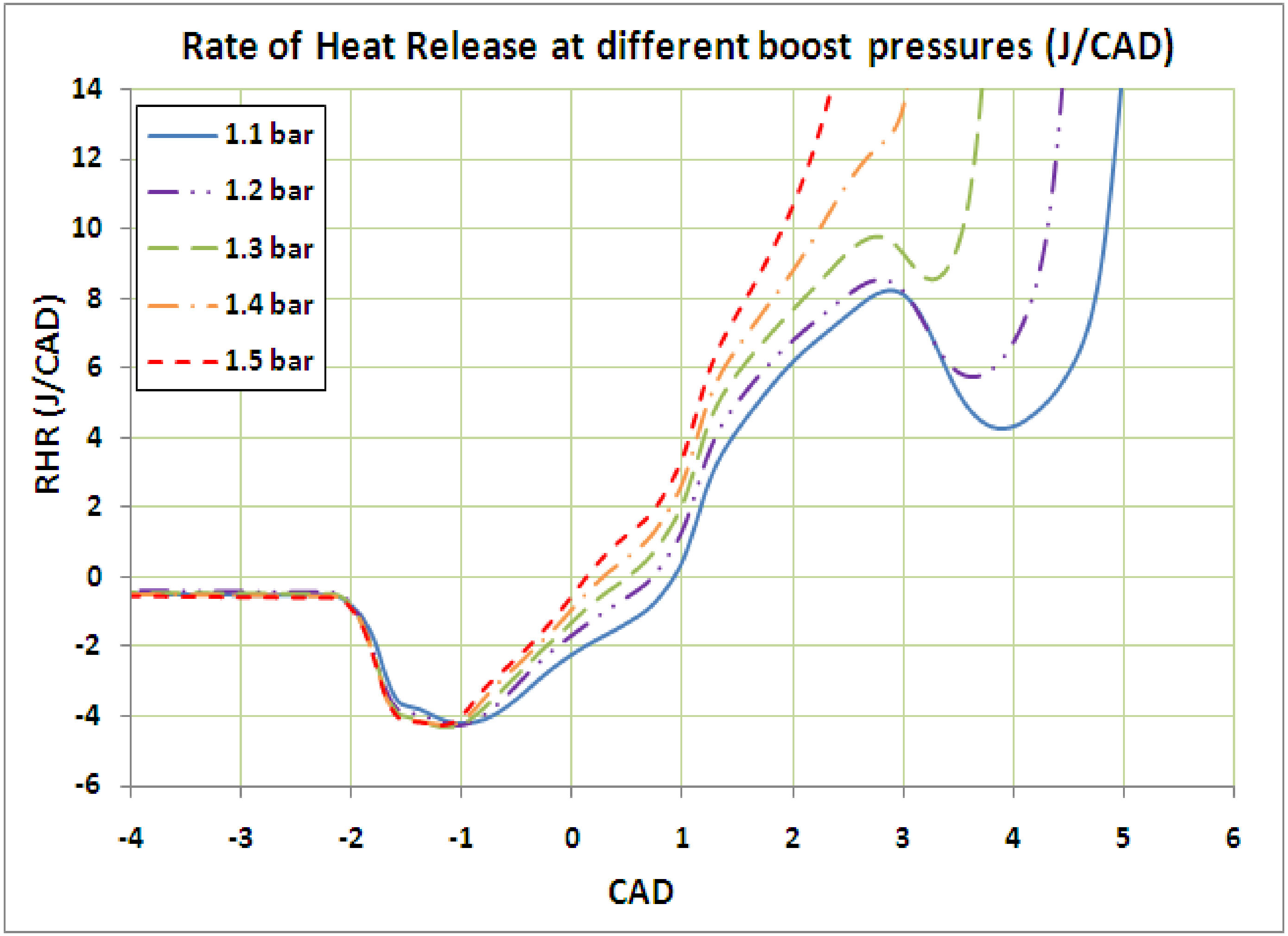


Comparison between 1.1 bar & 1.5 bar

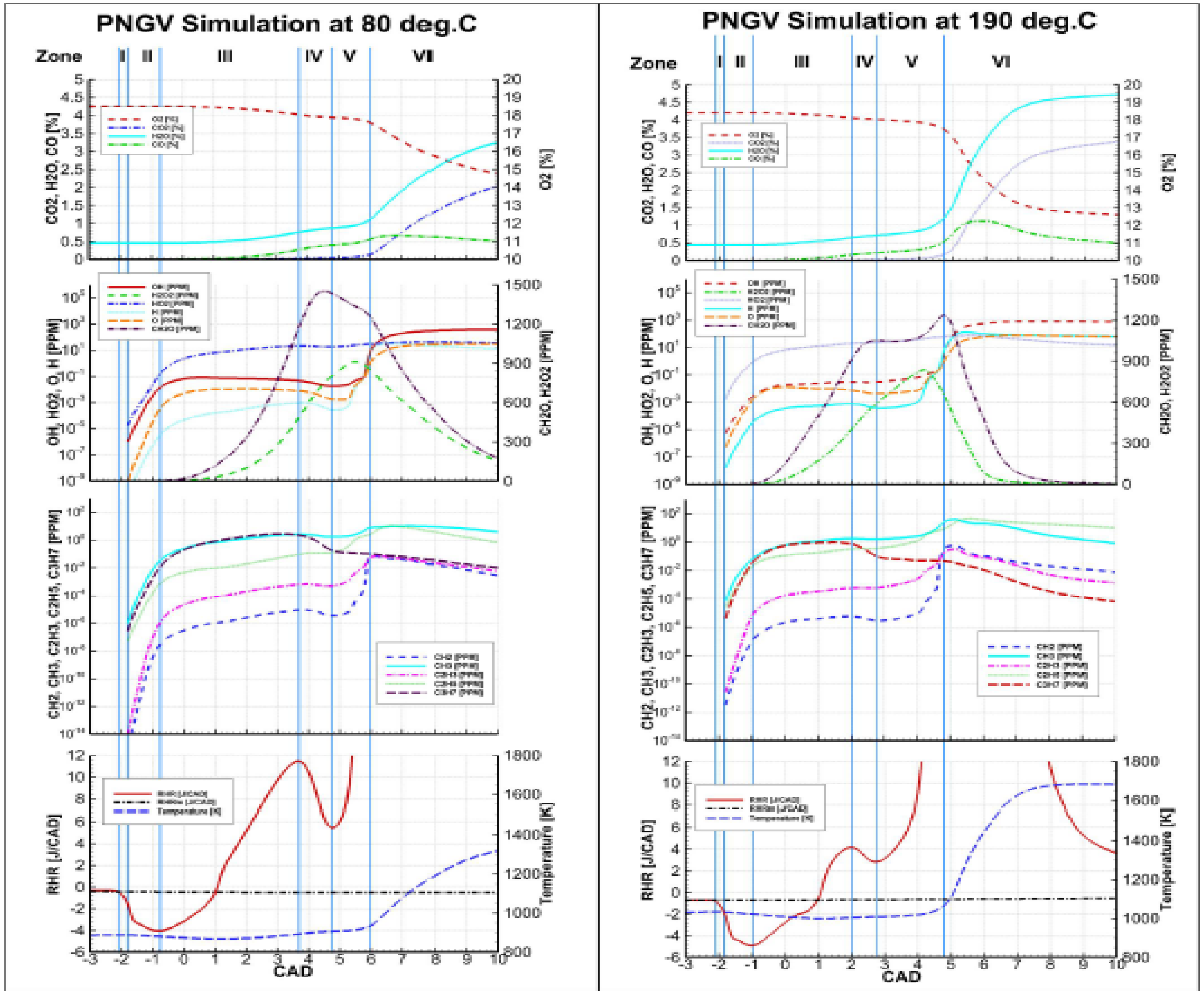




NTC at Different Intake Pressures



Comparison between 80°C & 190°C



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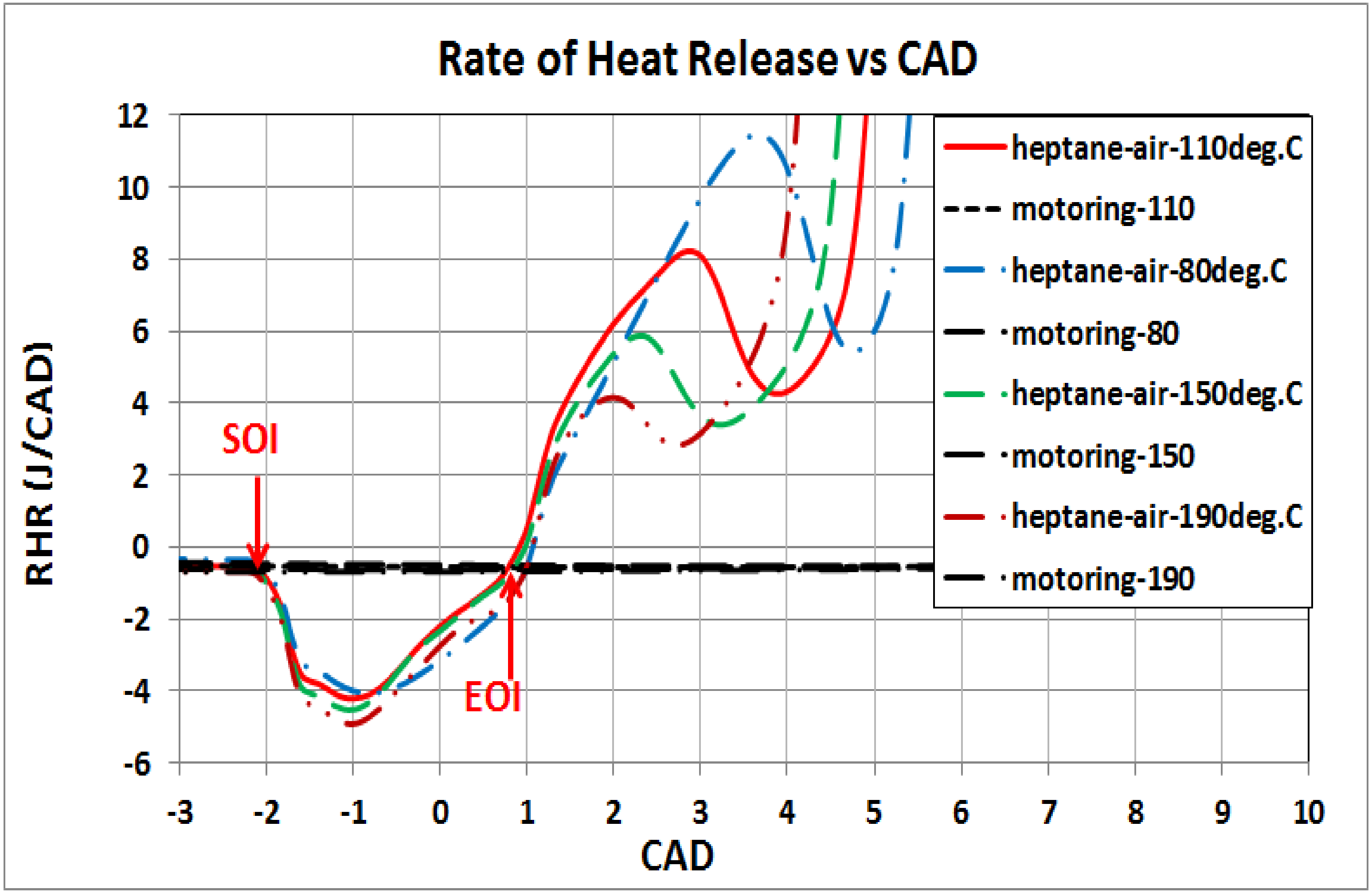
NTC at Different Intake Temperatures



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Experimental Results

Experimental Set-Up

- <u>Engine Specifications:</u>
  - Engine Type : 0.42 liter direct injection
  - Bore x Stroke : 79.5 mm x 85 mm
  - Compression Ratio :20:1
  - Number of valves: 4
  - Combustion Chamber : Re-entrant
  - Fuel Injection system : Common Rail
  - Injection Pressure: up to 1200 bar

Photograph of the Engine Setup

Test Matrix

EFFECT OF INTAKE PRESSURE	
FUELS	ULSD, JP-8 (HCN), F-T SPK, JP-8(LCN)
INJECTION PRESSURE (in Bars)	800
ENGINE SPEED (rpm)	1500
LOAD	**3 bar IMEP**
SWIRL	3.77
EGR	0%
START OF INJECTION	**-2.0 CAD* bTDC**
INJECTION DURATION	**0.358 ms**
INTAKE AIR PRESSURE	1.1 bar – 1.5 bar
INTAKE AIR TEMPERATURE	60^0C
COOLANT OUTLET TEMPERATURE	82.2^0C

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Test Matrix

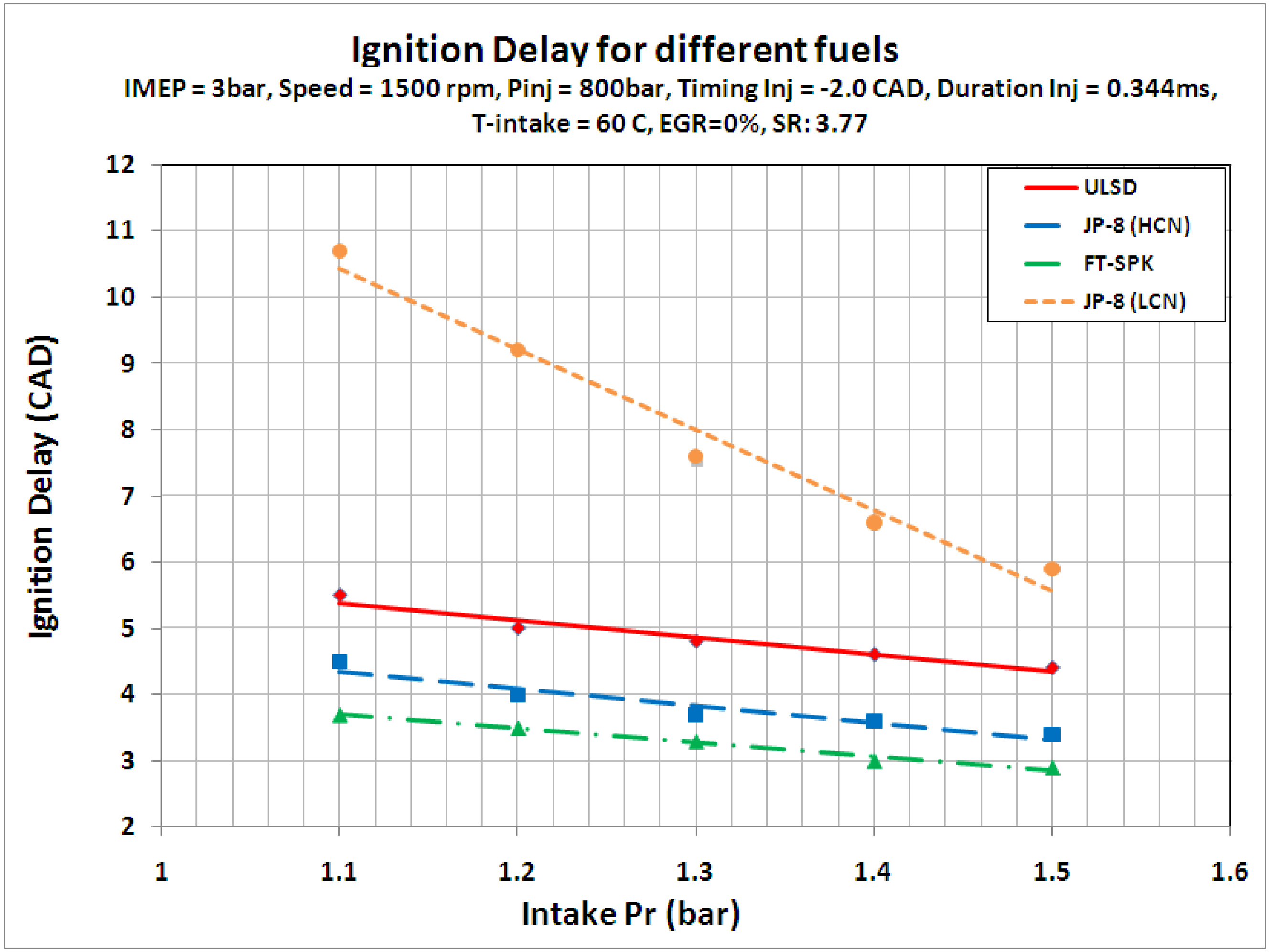
EFFECT OF INTAKE TEMPERATURE		
FUELS	ULSD, JP-8 (CN#44), S-8, JP-8(CN#31)	ULSD, JP-8 (CN#44), S-8, JP-8(CN#31)
INJECTION PRESSURE (in Bars)	800	800
ENGINE SPEED (rpm)	1500	1500
LOAD	**3 bar IMEP**	**5 bar IMEP**
SWIRL	3.77	3.77
EGR	0%	0%
START OF INJECTION	**-2.0 CAD* bTDC**	**-2.5 CAD bTDC**
INJECTION DURATION	**0.358 ms**	**0.402 ms**
INTAKE AIR PRESSURE	1.1 bar	1.1 bar
INTAKE AIR TEMPERATURE	30^0C-110^0C	30^0C-110^0C
EXHAUST GAS PRESURE	1.1 bar	1.1 bar
COOLANT OUTLET TEMPERATURE	82.2^0C	82.2^0C

***JP-8 (31) was injected at 6.0 CAD bTDC for 3 bar IMEP tests as the engine misfired at 2.0 CAD bTDC**

Fuel Properties

Property	ULSD	JP-8 (HCN)	F-T SPK	JP-8 (LCN)	Heptane
Flash point (^{0}C)	74	56.8	37.8	53	-4
Density (Kg/m3)	836.5	770	736.2	768.8	669
Derived Cetane Number (ASTM D6890)	46	50	58	31	56
Lower Heating Value (MJ/Kg)	41.2	42.1	44.1	44.0	44.6

Ignition delay for different fuels



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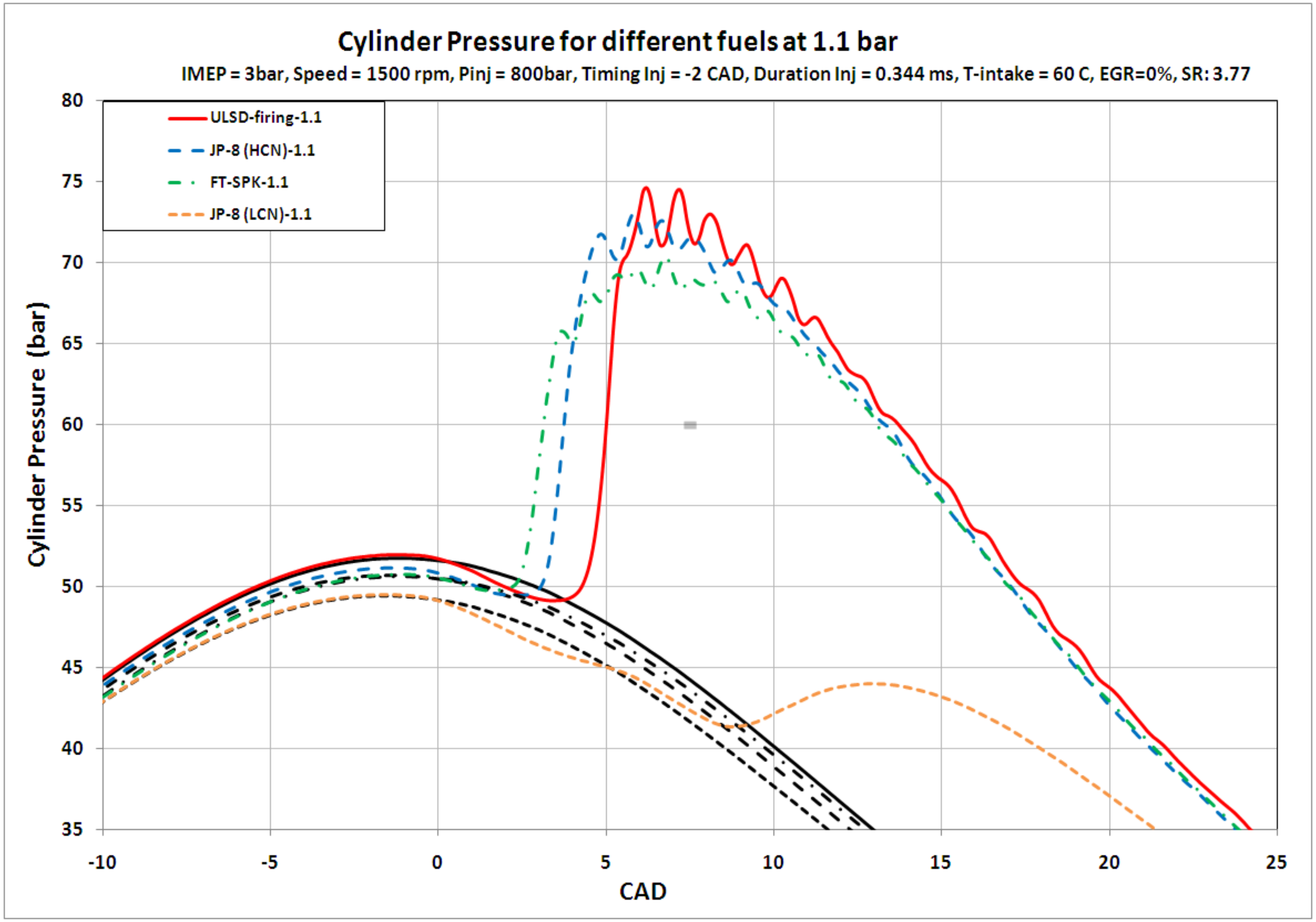
Cylinder pressure traces for different fuels



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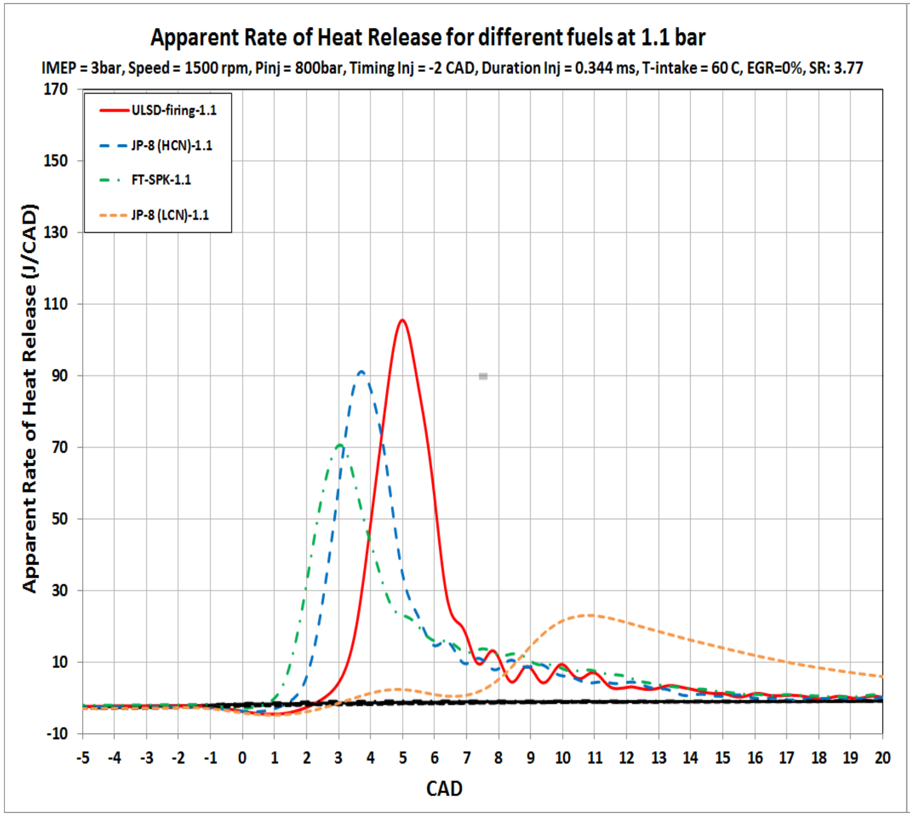
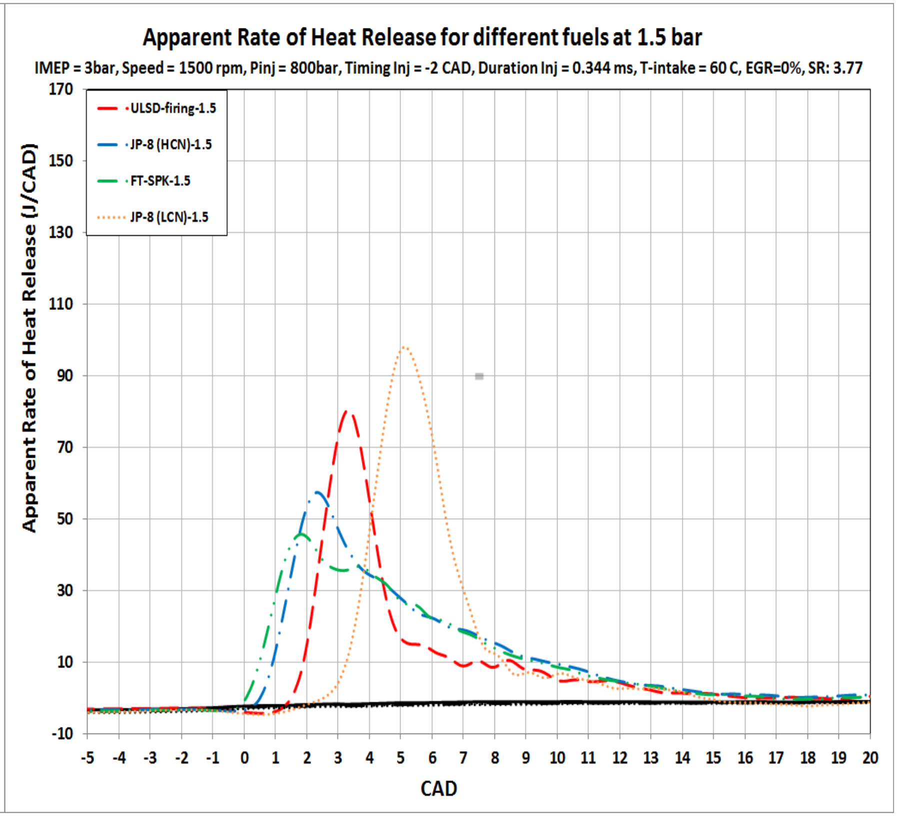
Apparent rate of heat release traces at 1.1 & 1.5 bar boost pressures





Physical and chemical Ignition Delays

	Duration from SOI to POI (CAD)		Duration from POI to SOC (CAD)	
Fuel	1.1 bar boost	1.5 bar boost	1.1 bar boost	1.5 bar boost
ULSD	2.1	1.9	3.4	2.5
JP-8 (HCN)	1.6	1.4	2.9	2
FT-SPK	1.5	1.1	2.2	1.8
JP-8 (LCN)	1.9	1.9	8.8	4

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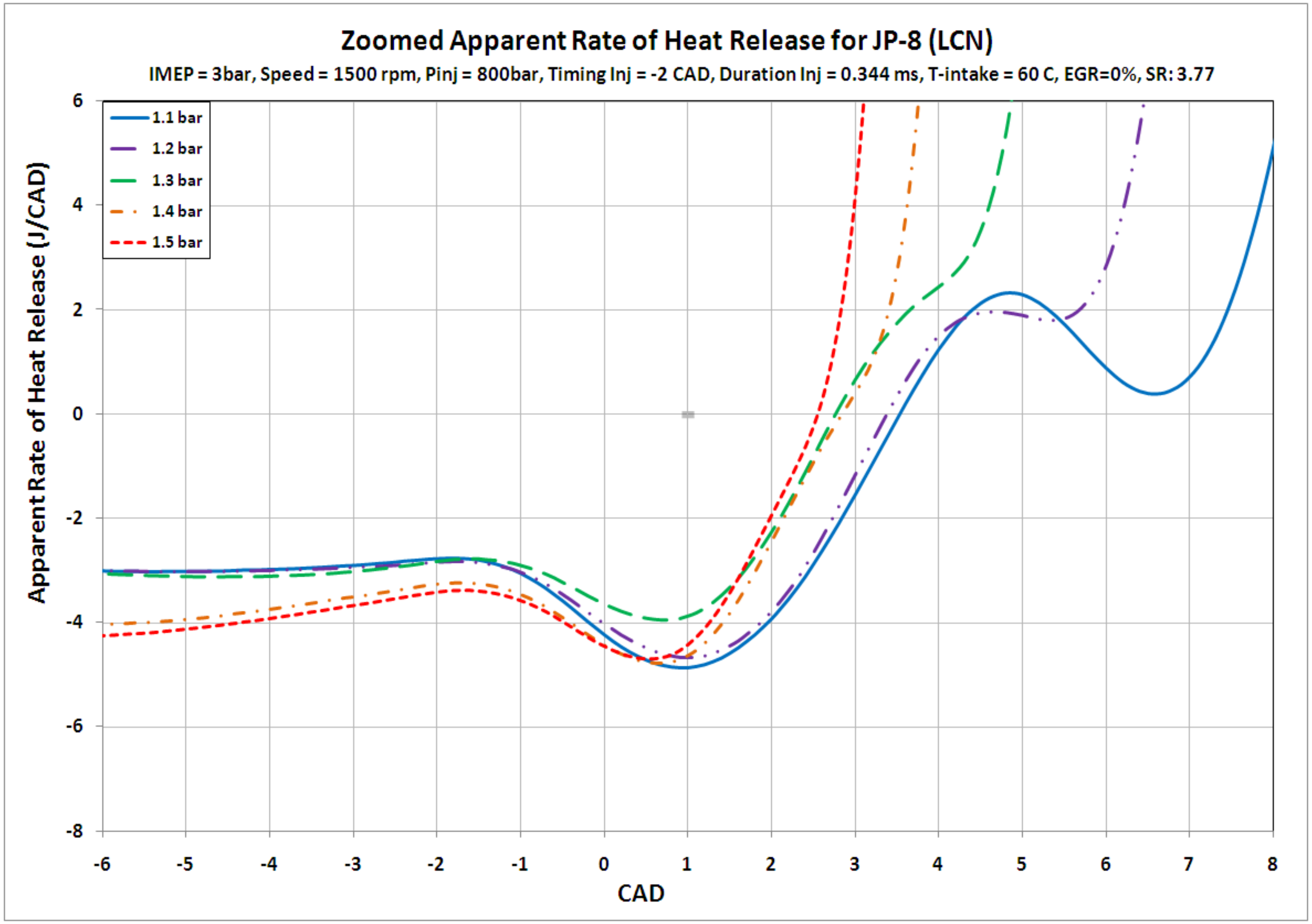
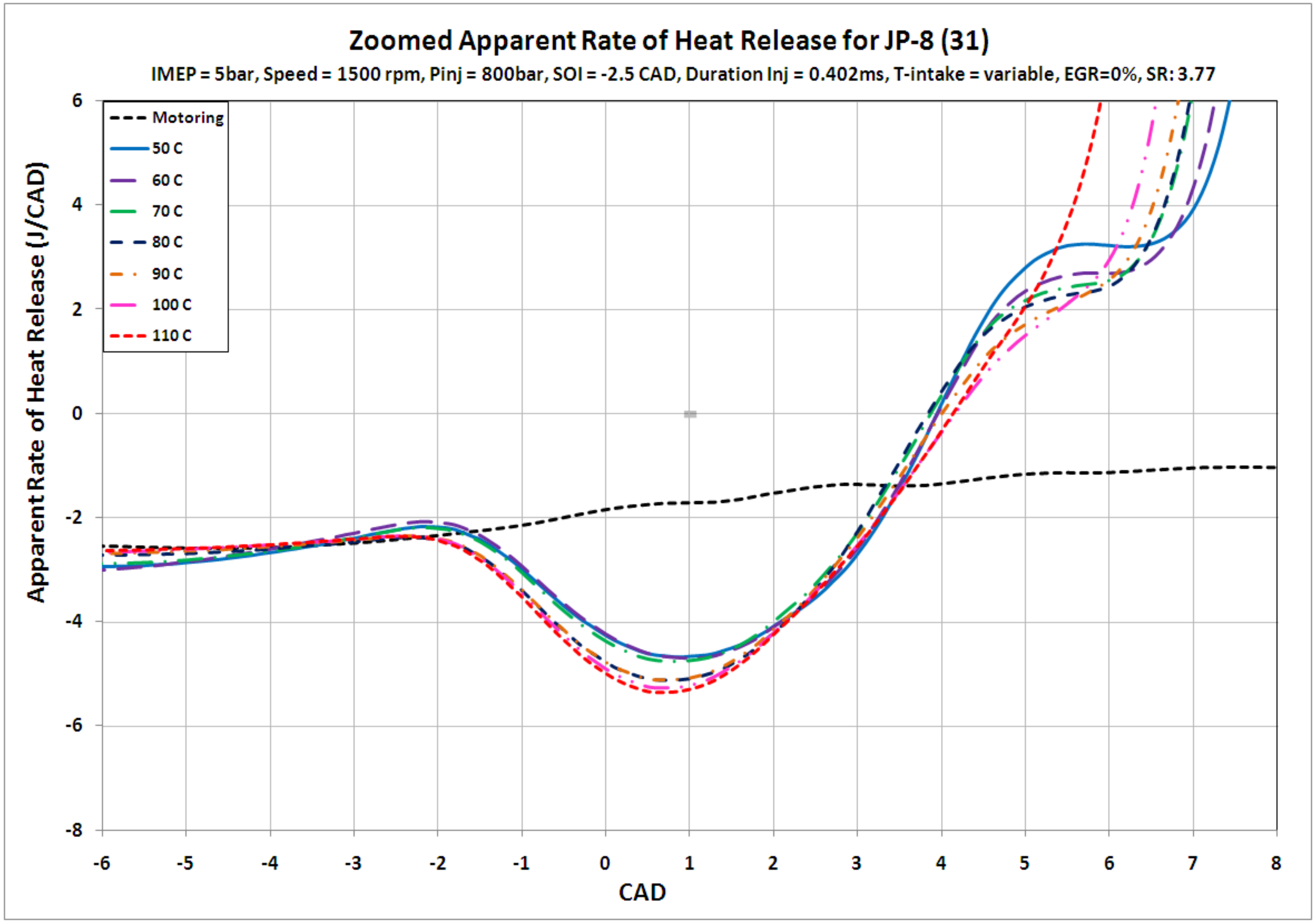
Auto-ignition regimes at different pressures



Auto-ignition regimes at different temperatures



Conclusions

- The 3D simulations showed the following:

1. The low temperature (LT: cool flames) and the NTC regimes occur during the auto-ignition of n-heptane under the engine operating conditions.
2. The LT and NTC regimes are reduced by the increase in charge pressure and temperature.
3. The Model demonstrated the major role the aldehydes and hydrogen peroxide play in the auto-ignition reactions.
4. The model predictions have been validated by the experimental results on the single cylinder engine at different intake pressures and temperatures.

Acknowledgements

- The authors gratefully acknowledge the sponsorship of this program by ARC: Center of Excellence sponsored by US Army RDECOM-TARDEC and led by University of Michigan.
- Special thanks are due to Laura Hoogterp of US Army RDECOM-TARDEC for her support of this program.
- The help of Dr. Paul Miles of Sandia National Lab and Dr. Inderpal Singh of Daimler are greatly appreciated .

Thank you for your attention

Questions?